National Aeronautics and Space Administration

Technology Evaluation for Environmental Risk Mitigation Principal Center

Hexavalent Chrome Free Coating Systems for Aerospace
Project Number: NT-1307

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Background

The replacement of hexavalent chrome [Cr (IV)] in the processing of aluminum for aviation and aerospace applications remains a goal of great significance within the aviation and aerospace community. Aluminum is the major manufacturing material on structures and components in both the aircraft (military and commercial) and space flight arena and consequently, the processing and maintenance of this material against degradation and corrosion is of prime importance to the US Air Force and NASA in preserving our defense and space operations capabilities.

Key to the operability and preservation of aluminum has been the use of chromated systems (conversion coatings, primers and hard chromium plated). Hard chrome plating on components is done through an electrochemical process; the electrochemically adhered chrome provides barrier protection to the substrate by forming a dense self-healing oxide layer on the surface. The electroplated chromium is chemically resistant to most compounds and offers excellent corrosion protection. Hard chrome plating also confers increased wear resistance and is most frequently used on landing gears, actuators, gearboxes, rotor heads and other high impact/wear components. Conversely, with applied coatings, the high corrosion resistance offered by chromated films is attributed to the presence of both hexavalent and trivalent chromium in the coating. The trivalent chromium is present as an insoluble hydrated oxide, whereas the hexavalent chromium imparts a “self-healing” character to the coating during oxidative (corrosive) attack. Hexavalent chrome coatings also play a critical role in supporting and enhancing the adhesion of the primer coating to the substrate.

Occupational Safety and Health Administration (OSHA) studies have determined that hexavalent chromium poses significant medical risks to users. Hexavalent chromium is considered a potential lung carcinogen. Studies of workers in the chromate production, plating, and pigment industries consistently show increased rates of lung cancer. It has also been shown that direct eye contact with chromic acid or chromate dusts can cause permanent eye damage. Hexavalent chromium can irritate the nose, throat, and lungs and repeated or prolonged exposure can damage the mucous membranes of the nasal passages and result in ulcers. In severe cases, exposure causes perforation of the septum (the wall separating the nasal passages). It has also been proven that prolonged skin contact can result in dermatitis and skin ulcers. Some workers develop an allergic sensitization to chromium and kidney damage has been linked to high levels of dermal exposures.

While chromated systems (applied coatings and plated) have set the bar for treatment and protection of aluminum, it is now known that hexavalent chromium is carcinogenic and poses significant risk to human health. On February 28, 2006 OSHA lowered the 8 hour time-weighted average (TWA) Permissible Exposure Limit (PEL) for hexavalent chromium from 52 µg/m3 (micrograms per cubic meter of air) to 5 µg/m3. OSHA issued a deadline of May 31, 2010 for employers to comply with this PEL through the implementation of engineering controls. The final rule also includes provisions for employee protection such as preferred methods for controlling exposure, respiratory protection, protective work clothing and equipment, hygiene areas and practices, medical surveillance, hazard communication and record keeping. In the interest of worker safety, as well as the cost and operational implications of new and pending environmental, safety and health regulations, both NASA and the US Department of Defense (DoD) continue to search for alternatives to hexavalent chrome in applied coatings and plating applications that meet performance requirements in corrosion protection, cost, operability, and health and safety; while underlining that performance must be equal to or greater than existing systems.

Objective

Objective is to test promising coatings identified from Phase I of TEERM Non-Chrome Coating System Project (http://www.teerm.nasa.gov/projects/NonchromateCoatingSysFor%20Aerospace.html) and several new materials to additional stakeholder identified specifications. Overall objective of the TEERM Hexavalent Chrome Free Effort is to evaluate and test a fully hexavalent chrome free coating system (pretreatment, primer and topcoat) as well as several pretreatment & primer only systems as replacements for hexavalent chrome coatings in aircraft and aerospace applications.

Period of Performance

- August 2008 to December 2011.

Stakeholders

NASA Centers (Johnson Space Center (JSC), Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC); Space Shuttle Elements/Prime Contractors; Constellation Program, Orion Program, Shuttle Environmental Assurance initiative, U.S. Air Force (Hill Air Force Base, Air Force Materials & Manufacturing Directorate and Wright Patterson Air Force Base Coatings Technology Integration Office), Navy (NAVAIR) & Army, ATK, Lockheed Martin, Northrop Grumman, Boeing, United Space Alliance, Raytheon and Spirit Aerosystems.

Benefits

- Meets environmental and safety regulatory requirements
- Reduces need to monitor for chromium exposure due to new regulations
- Decreased risk of environmental, worker and public exposure
- Reduced maintenance cost and government liability

Recent Progress

- All Testing has been completed, data analysis is continuing – May 2011

Document Status

- Completed Interim Test Report – May 2011

Milestones

- Identified 200+ full coating system tests, 80+ pre-treatment and primer tests and 95+ pretreatment only tests that have been performed in researching historic non-chrome research / testing – October 2007 – March 2008
- Developed final draft of Joint Test Plan / Testing Approach – August 2008
- Pad test site setup – September 2008
- Began coordination/communication with Constellation Program regarding testing of non-chrome coatings – March 2008
- Began coordination with OEMs, DoD Agencies (Air Force, Navy) on coordinated testing – March 2008
- Completed initial draft Joint Test Protocol and initial draft Potential Alternatives Report, which recommended included the coating systems to be tested – March 2008
- Identified test sites for atmospheric and 2,000 hour salt fog test – May 2008
- Identified in-kind test site for bare corrosion resistance testing – August 2008
- Identified in-kind test site for adhesion testing – November 2008
- Initiated testing of Air Force coated panels at launch pad and beach test sites – November 2008
- Initiated testing of corrosion rate panels at pad – November 2008
- Three Systems from Phase I, 4 from Navy/DoD Testing and 1 Un-tested will be a part of this Hex-Chrome Free Coatings Project
- Additionally Coatings (11 in total) from Ares and AF are a part of the project
- JTP Draft Completed in October 2008
- AF Coupons, some Ares Coupons and Corrosion Rate Coupons have been placed at test sites at KSC (November 2008)
- Completed test panel preparation guidance document with stakeholder approval – December 2008
- Everyone has their panels: Spirit, MSFC, Hill AFB, KSC
- Completed all Phase I Testing (Salt Fog, Cyclic Corrosion, Filiform Corrosion, Hydrogen Embrittlement, Adhesion (Patti Jr.), Dissimilar Metals)
- Ares Upper Stage Panels were shipped to KSC for Atmospheric Testing - March 2009
- All panels have been painted and will be placed at the test sites or shipped to test facilities in April 2009
- Galvanic Couples corrosion resistance was being prepared at MSFC and will be in place at KSC by July 2009
- Complete Final JTP for Phase II - June 2009
- Begin laboratory testing for Phase II - May 2009
- JTP Final as of June, 18, 2009
- Adhesion Testing at Hill AFB Completed – June 18, 2009 – All Systems PASSED
- MSFC completed bare corrosion resistance testing (pretreated only) – March 2010
- Completed 3000hrs Salt Fog Testing – April 2010
- Two hex chrome free coatings were selected for testing in the Combined Environment Lifecycle Corrosion Analysis Project – April 2010
- Completed 12 Months Atmospheric Exposure (of 18 Months) at LC-39B and Beach – May 2010

- Test panels at Spirit Aerosystems in Wichita, KS have undergone 3000 hr salt fog on 2 alternatives and 1 control.
- Test Panels at the Beachfront Corrosion Test Facility and Launch Complex 39-B have been exposed for 18 months as of November 17, 2010 . All but two systems show good performance, several with little to no signs of corrosion.
- Received draft test report from atmospheric testing – December 2010
- Completed initial data analysis of test panels – April 2011
- Began analysis of Combined Environment Cabinet panels – April 2011
- Completed literary research on lifecycle costs of using hexavalent chrome – May 2011

Future Goals

- Complete Analysis of Combined Environment Test Panels – September 2011
- Draft All Inclusive Final Report – September 2011

Updated 07/01/11